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Microphones and Their Placement

By the Engineering Department, Aerovox Corporation

Microphones and equalizers; their types, placement and application in motion picture and television recording.

The operator's tools, consisting of various microphone types; booms and stands; wind screens and equalizers.

Techniques in recording sound effects, pre and post-scoring of music, and pick-up on sets requiring equalization of dialogues between several different sound levels.

THIS article will be confined to microphones and their placement, as this applies to motion picture recording and television pickups. We will touch briefly on the historical development of microphones used in broadcasting and motion picture pickups in the order of their common usage. We will deal first with the tools of the business, beginning with the microphone.

The term "microphone" is an outgrowth of the development of the telephone transmitter. During these early days a large variety of means were devised to convert varying pressure waves into electrical impulses, permitting them to be recorded, amplified, reproduced or transmitted. To certain of these most sensitive devices the term "microphone" was applied.

The first and earliest of these is the carbon microphone, the original models being composed of a cylinder of loosely packed carbon granules between conducting terminals, the cylinder being fitted with an elastic diaphragm attached to a piston which compressed and decompressed the granules, varying the resistance across the two terminals.

Later, push-pull microphones were developed, with a button on both sides of the diaphragm. This in turn gave way to the second type of microphone which came into common use and was employed almost exclusively in the very early stages of motion picture recording, and was known as a condenser microphone. The carbon microphone at this point, dropped into relative obscurity, becoming almost extinct, and is no longer used in any field of microphone pickup. This condenser microphone consist-

FOREWORD

The material contained herein is based on a paper by Mr. Arthur Davis, General Manager, Western Research Laboratories, Aerovox Corporation. This paper was delivered for Mr. Davis by Mr. Philip Erhorn at a lecture course of the Audio Engineering Society, on November 14, 1957, in New York.

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ed of a diaphragm only, spaced very close to a solid plate, so that when pressure waves were impinged on the diaphragm, the capacitance of the condenser was varied. This microphone was in use for several years, until the advent of three new types; the crystal microphone, the moving coil dynamic, and the velocity ribbon microphone.

Until the moving coil dynamic and the ribbon types made their appearance, all microphone pickup patterns were omni-directional. The ribbon and the moving coil dynamic gave us directional qualities, the ribbon microphone being the most effective in that it had what is known as a figure eight pattern, with the greatest pickup being directly in front, or directly in the rear, of the microphone, having very little pickup off the sides. After the ribbon, and the moving coil dynamic came into being, these microphones were assembled into one unit with acoustical chambers, etc., to produce various microphone patterns suitable for different types of microphone pickup recording. For example, the cardioid pattern microphone is achieved by assembling these two microphones, and phasing their outputs by acoustical means in such a manner that they achieve a cardioid or heart shaped pattern, giving the front of the microphone the greatest pickup range and area, and having relatively little pickup off to the side or at the rear of the microphone. This type of microphone for dialogue pickups has become most useful in this field.

The last on the scene has been a revival of the old condenser microphones, but considerably different than the earlier models in that the diaphragm diameters and spacing have been greatly reduced, enabling the diaphragms to be stretched so their resonance is out of the audio range. Some of the foreign-made condenser type microphones have appeared with two gold sputtered plastic membranes for diaphragms, the rear diaphragm being out of phase, giving a directional pattern. These microphones are excellent for all types of pickups, since due to their lack of resonant peaks through the pass band, they have a very high degree of perception.

The microphones we have discussed to this point fall generally into the following categories: The condenser, and the crystal or piezoelectric microphones are compliance controlled; dynamic microphones are resistance controlled devices; ribbon or velocity microphones are mass controlled; and a cardioid microphone is mass and resistance controlled.

In the following comparison of these microphone types we will enjoy the term "recognition factor", which is extremely important in the recording of dialogue. This may be defined simply as the degree of recognition of reproduced sound to the original sound.

The plain dynamic, or pressure type mcirophone, has a high degree of ruggedness, compactness, and high output level. However, they do not have the best quality, their frequency response characteristics are usually not too good, and they have a good many resonant peaks all through the pass band. The ribbon, or velocity type microphone, has excellent frequency response and directional qualities, high recognition factor when not too close to the sound source, and a lack of mechanical resonances through the pass band. They do, however, have a very low output, are extremely fragile, and subject to air and wind currents. The crystal microphones also have a high recognition factor, are small and compact, and have a very good frequency response through the pass band, with very little resonance, and can easily be made directional. Their disadvantages lie in their fragility and sensitivity to temperatures such as are encountered in normal recording operations. They also require a preamplifier right at the microphone. These crystal microphones are very rarely used in motion picture recording, so we will not allude to them further. The condenser microphones, particularly those with diaphragms which are stretched to resonate above the pass band, are excellent devices. They have an extremely high recognition factor, are light and compact, and have virtually no mechanical resonance peaks through the pass band. Since they have only a single thin diaphragm, they have virtually no mass. They can be made to be directional, although to our knowledge there are no condenser microphones made with directional qualities, with the exception of the foreign manufactured models.

There is another type of condenser microphone, which we shall mention at this point. One type uses the direct method, where the variation of the capacitance of the diaphragm to the back plug is amplified directly, and the other is where the capacitance of the diaphragm works into a discriminator circuit, using the FM carrier principal. These microphones have virtually no distortion, and the signal to noise ratio is greater than can be achieved by any other method. In my opinion, the reproduction of this type of microphone tops that of any other. Unfortunately, they have not gained wide acceptance due to their cost, and to the extreme difficulty in keeping the discriminator circuit in adjustment.

Of these many different microphone types we have discussed, there are three general types that are in common usage at the present time: the pressure, or dynamic microphone; the velocity or ribbon microphone; and the direct amplified condenser microphone. For the balance of this article we will deal only with these particular types, and we will refer to them as the ribbon, dynamic and condenser microphones.

In considering the other tools used in microphone pickups, the boom or microphone stand assumes almost as much importance as the microphone itself. The stands are relatively simple, consisting of a base on which to mount the microphone, but a good boom is a fairly complex piece of equipment. These generally are made up of a main pedestal mounted on a mobile rubber-tired dolly, with a platform high enough to allow the operator to stand above the boom proper. On top of the pedestal this movable, inclined arm or boom is swivel-mounted in such a manner that the operator can swing it over the entire set. The main boom is a telescoping device which can be cranked noiselessly in and out during takes. Also, a telescoping control rod on the boom can be rotated by the operator's hand to swing the microphone in a 360° circle.

At the end of the boom the microphone is suspended and balanced so that the center of gravity of the microphone is in the center point of the suspension. All pulleys and moving parts of the boom must be extremely noiseless. The cables draped on the boom are specially fabric braid covered for maximum flexibility, to follow every movement of the boom. Rubber cables are unsuitable for this type of work, as they squeak and make noises running over the pulleys. In the boom the operator has a piece of equipment which allows him freedom to maneuver the microphone to follow actors across the set, up and down stage, and face the microphone always in line with the persons talking. With a good boom the microphone can be flipped 180° back and forth during dialogues between two persons.

The fishpole boom is a much less complicated device than the stage boom, but is particularly adapted for use on exteriors, and in the making of Westerns. This consists of a long pole, with a cable running through the center, and a microphone hung out on the end. It is held in the operator's hands like a large wand, and with this wand he can maneuver the microphone into position. The microphone is suspended on the pole at about a 45° angle, so that by rotating the pole, it can be faced in one direction or another. The fishpole boom is used chiefly on outdoor shots where a large stage boom would not be practical.

In any discussion of microphone pickup tools, the wind screen, although it is actually a more or less minor tool, must be taken into consideration. This is not always used, except for exterior shots, but becomes an essential piece of equipment if there is any movement of air. Quite often sub-audible blasts of wind that will rattle microphone diaphragms are present even on days where very little air disturbance can be detected. These small air blasts are very annoying, and can be easily avoided with a good wind screen. The screen will consist of a wire cage covered with two or three layers of silk or gauze; or one layer of gauze and two or three layers of silk stocking material. Sometimes two concentric spherical cages, one within the other, will be even more effective.

For reducing low frequency resonances and improving tonal quality of voices through the reduction of hum and other low frequency noises, the dialogue equalizer has become an indispensable tool in the hands of the audio engineer. An equalizer is a frequency discriminating network which produces a desired variation of attenuation over a range of frequencies. There are an unlimited number of applications of different types of equalizers available in the audio field. We will, however, confine our discussion to those directly connected with microphone pickup.

On television and motion picture sound stages, large, low frequency variations are inherent. These low frequency stage noises will sometimes blanket the entire microphone pickup. Since it is not uncommon for different stages to have variations in low frequency response characteristics, the low frequency dialogue equalizer would consist of a semi-variable type, variable by means of either a key or links on terminals which can be set at the beginning of a show. It would be a high pass filter, having a hinge point at 300 cycles, with a fairly rapid roll-off below 200 cycles, and having four adjustable steps at 0, 4, 8 and 12 db at 100 cycles. These taps or steps should be so arranged that it is possible to lock the equalizer into position and not disturb or move it during the take of a complete show on a particular sound stage with characteristic acoustical conditions.

The high and dialogue equalization requires a different type of device. This should be easily variable by means of a knob with finer steps, allowing changes during takes if necessary. Such a device would take the form of a variable high end equalizer which would enable the operator to raise the high end from the flat characteristics to a maximum range of 0 to 12 db at 5,000 cycles. These steps should be of approximately 2 db so that the mixer can vary them during takes, because as the microphone swings around a set and moves away from the performer there is a disturbing or noticeable gain in low frequency characteristics of the set, and a loss in the high frequency. This variation in frequency response occurs so rapidly that an easily accessible knob is necessary in order to make corrections.

There is another type of equalizer that is used to great advantage in the subsequent re-recording of takes. This equalizer functions as a depressant in the high ranges in the 3,000 and 5,000 cycle band, for the purpose of removing objectionable sybillants which were not detected during the actual take.

The foregoing is a fairly complete coverage of the tools required for motion picture and television recording. Before proceeding with a discussion of their usage and application, we would like to bring out a few pointers regarding their maintenance. These tools, like the tools of any profession, require constant care and attention in order to maintain peak performance. We recommend that microphones be kept and used by the same operator, since the operator gradually becomes accustomed to the idiosyncracies of these devices and can in time acquire a proficiency in the use of one or more of his own microphones. Proper care of microphones is essential to keep them at the peak of their performance. When not in use, they should be stored in their proper receptacles to keep them dirt-free and enable them to be transported without damage. Dynamic and ribbon microphones are prone to attract tiny bits of iron particles that may be present in the atmosphere. These adhere to the microphone and eventually load it with fine metallic particles. To clean the microphone, roll a bit of scotch tape, sticky side out, onto the end of a toothpick and carefully slide it around the edge of the magnets. In this way the particles can be picked up and removed from the microphone without disassembling the entire unit. In caring for the boom the most essential point to keep in mind is that all pulleys and slides, cables and rods, and each moving part be kept scrupulously clean and dirt free to prevent rumble, and be well-oiled so that they operate with ease. Proper counterbalances should be provided to exactly match the weight of the microphones and other gear hanging on them.

To understand sound microphone pickup techniques, one should have a fair knowledge of the nature of acoustics and sound itself. Sound pressure waves are a series of continually expanding wave motions, produced by alternate compressions and rarifications of the atmosphere. When sound travels, the air itself does not travel from the origin of the sound to the pickup point. The expanding pressure wave is propagated through the air by the transmission of the energy to the molecules in the atmosphere, which oscillate forward and backward. We might refer here to the well-used analogy of the propagation of a bump or a jerk from the engine at one end of a freight train to the caboose at the other. The elasticity of the atmosphere will of course vary with its density depending on altitude. At sea level, which is approximately 15 lbs. pressure per square inch, the speed of sound wave propagation is 1100 feet per second.

To illustrate attenuation we might mentally convert the rigid structure of the train to one of soft, compliant rubber, which, when bumped at one end, would diminish the transmission of this original wave of energy until it reached a point of complete absorption before arriving at the caboose end. This would demonstrate attenuation caused by the medium itself, indicating infinite attenuation on the rubber train, which will vary in the ratios of time and distance. The amplitude of the pressure waves is attenuated, therefore, depending on the compliance of the medium or atmosphere, which is affected by atmospheric pressure, thermodynamic

factors, and other existing conditions. As the speed of propagation depends on the density of the medium, it follows that at higher altitudes the attenuation would be greater, as the speed through the air would be slower.

The natural attenuation in the compliance of the medium, distance traveled, and the attenuating effect of the microphone itself, are factors to be taken into consideration. A microphone with a diaphragm of one-half inch diameter is sampling a very small portion of this pressure we have, and the further from the source the smaller the sample of directly radiating energy.

Of particular importance is the effect of the acoustics of the stage or set. When these pressure waves or bubbles hit obstructions and walls, they will either be reflected or absorbed, depending on the material of which the obstruction is made. The reverberation or re-echoing of sounds among the various solid surfaces may detract from the audio intelligibility. The reflected sound also is in the shape of an expanding bubble which, depending on its phase in relation to the original, may either increase or decrease the amplitude at the time of impringement on the diaphragm of a microphone. This condition can cause serious problems in the recording of speech, since speech depends entirely on how faithfully the reproduced sound compares to the original sound. In the recording of music this is not such an all-important factor. In fact, a condition that is very detrimental to speech recording may be extremely pleasing to the ear in music recording. As, for example, the popularity of the echo chamber technique used in recent years to add a quality to popular music and vocal recording that would be unbearable if applied to the recording of dialogue. So the problems dealt with in recording music become an entirely different set of circumstances than those involved in the recording of speech.

Attaining proficiency in the recording of speech which can be reproduced with the maximum recognition factor is an exacting skill that can only be achieved by experience. As is true with all highly skilled trades, it is almost impossible to point out all of the "do's and dont's" of microphone pickup on a set, since only through trial and error can the operator become really familiar with the job he is doing. Any operator who is new at the business should be extremely diligent in meticulously listening to and reviewing as many of his own dailies and recorded tracks as he possibly can, until he is able to achieve consistent results. In this way he will gradually become accustomed to the peculiarities of recorded sound as compared to sound as interpreted by his own ear on the set, and thereby develop his individual techniques for producing good recorded sound. No skilled workman can ever learn to do his job well unless he sees the end results of that job, and I can not stress too greatly the importance of the operator's spending a great deal of his time in this critical reviewing of his own recorded tracks.

Good dialogue and speech pickup requires the cooperation of a two man team, one operating the boom and microphone and the other mixing and monitoring and doing the equalizing. Never should more than one microphone at a time be used on a speech pickup, not even in stereophonic recording. The separation and positioning of sound in stereophonic is done later in dubbing. To achieve the best results we also require close cooperation with the cameraman in order to obtain the maximum benefits of dramatic effects.

One of the primary considerations which must be stressed in the pickup of dialogue is the importance of achieving consistency of quality. The ideal of course would be to have the microphone at all times about eighteen inches from the lips of the speakers, by which a near perfection can be attained. This ideal situation is usually possible in broadcast pickup, but in motion pictures and television broadcast this is out of the question since we have to consider the picture as well. So we will have to compromise and take something not as perfect as we would like, but settle on a technique which will allow about 50% of perfection and attempt to maintain this quality at all times.

It has been proven that the human ear can tolerate a great deal of frequency distortion, provided these distortions do not vary with time. Articulation tests of intelligibility show that listeners get a poor score when the frequency response is suddenly altered. Intelligibility scores pick up as the listener's ear becomes conditioned to the change. So it can be seen that to achieve and maintain a consistent pickup quality is of vital importance if we are to avoid distracting the audience by dialogue sound reproductions of varying frequency responses.

The boom operator should size up the stage and the set, prior to the actual recording, to familiarize himself with the acoustic problems that will be encountered. If he is working on a small set he should check to see if there are hard walls and surfaces that will be encountered in swinging the microphone around and keeping it on certain performers. For instance, if the action during the take requires the performer to walk across the set close to a mirror, the microphone may have to be placed slightly off beam at this point to avoid a reflected slap-back of sound from the mirror itself. This will become noticeable by resonant peaks. He should ascertain from the cameraman what the exact camera angles during the action will be, and work out his plans to maneuver the boom around the set to stay at all times as near in front of speaking actor's face as possible, maintaining a minimum distance of from eighteen inches to three feet for closeups, and possibly five to six feet or more on medium and long shots. Also, it is necessary to bear in mind the peculiarities of the particular type of microphone that is being used. Some microphones, such as the dynamic microphones, are not too critical as to orientation. Ribbon microphones, on the other hand, are extremely critical. The sensitive axis of the microphone should be aimed toward the actor's belt line, with an angle of about 40° to the actor's lips for cardioid microphones, and approximately a 60° angle for dynamic microphones. These types of pickups will sometimes drop the level at the 5,000 cycle range from four to ten db, depending on the distance and the angle of pickup. At this point it will be necessary for the mixer to adjust the 5,000 cycle peak of the dialogue equalizer, bringing it up in the higher frequencies.

The mixer should set his high pass equalizer to roll off the low end, to give the most consistent low end quality whether the actor is talking within three feet or eight feet of the microphone. This will vary somewhat with different stages. A typical stage might have a reverberation time of about three seconds at 100 cycles, one second at 1,000 cycles, and three tenths of a second at 10,000 cycles. By this it can be seen that the further a microphone is moved away from the source of sound, the greater percentage of room noise and reverberation charactistics of the room he will get in relation to the direct pickup. The longer the reverberation time, the more objectionable the pickup of this reverberated sound.

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Also, the speaking habits of an actor will have a great deal to do with the quality of the pickup. In dialogue between two persons with fairly similar speaking voices, the best positioning for the microphone is about equi-distance between them. Should you have the problem of recording dialogue between two actors whose speech levels vary greatly, one should be favored over the other. The operator must swing the microphone around from one to the other as they talk back and forth, even though he has to make a swing of 180°. This is usually done by rotating a shaft on the microphone boom. And here one must stress again how vitally essential proper maintenance of your equipment can be, in order that every moving part of the boom is quiet in its operation.

The mixer should at all times be very alert to the quality and character of background noises present during recording, since stage noises and such can make tracks impossible to match up. Sometimes, when making pickups on very jumpy backgrounds, from long shots to closeups, and back again, it may be necessary to mask some of this with suitable sound effects or a background of music track, because there are times when it is virtually impossible to get perfect matches of tracks.

Recording sound on location out-of-doors presents an entirely different set of problems than those dealth with in stage and set microphone pickups. When recording exterior shots, we are actually working in a reverberationless set, and the high frequency losses are greater. Extraneous noises are more prevalent and difficult for the operators to detect out-of-doors. Sounds that do not belong in the picture may go unnoticed by the operators while the picture is being shot, but be very annoying to the extent of making the recorded dialogue almost unintelligible to an audience. For instance, during the filming, the operators may be aware of a running stream nearby, but since it is in the locale, it becomes to them a natural part of the scenery. However, the noise of running water will sometimes pick up very loudly, and if the stream does not show in the picture, but the audience hears it, this can be extremely distracting. By being around the actors for hours between takes, the operators become used to many existing noises and automatically eliminate them from what they hear during the shooting of pictures. The clink of coins in people's pockets as they walk through sets is sometimes undetectable during the filming, but is a glaring distraction when shown on the screen, because there is no logical reason for this particular noise.

On the other hand, many times these background noises are a desirable and necessary part of the sound track, contributing to the dramatic story effects. The clink of keyes and coins, the metallic jingling of bells on harnesses, the chittering of a flock of birds in a tree, usually do not come through unless the right type of microphone is used. If a microphone with a low recognition factor is being employed these noises may not be noticed by the crew when listening on the ear phones or the monitor, but will be picked up and reproduced as background steam. This is due to shock excitation of the ragged response of microphones, whereas if the right type of microphone were selected, these would become a part of the scenery and be recognizable on the screen for what they are. With careful microphone selection these extraneous sounds can be turned from a curse into dramatic effects. Condenser microphones, with their high recognition factor, are an excellent choice for this type of pickup. Ribbon microphones are also good, except for their susceptibility to the slightest wind current.

Vocals for motion pictures are not usually too difficult to record. They are handled much in the same manner as broadcast pickups, with the actual recording of the vocal track being made in an isolated recording booth or studio. Here the artist sings to the accompaniment of an orchestra, or of recordings that have been pre-scored. This accompaniment is piped to him through earphones, and only the vocal track is picked up at that time. These tracks are then separated and scored before the picture is made, so that during the filming the vocals are played over a loud speaker on the set, with no sound being recorded at that time, and the vocalist merely makes lip movement or sings along with his own vocal recordings. The microphone technique in this case is generally the use of a microphone stand in a recording studio which has the necessary acoustical properties for vocal recordings. If a vocalist has had previous microphone training he will know exactly how to keep his proper distance from the microphone for various musical passages. However, if the artist has not been trained in correct recording procedures, the operator will need to instruct him in keeping a correct distance from the microphone at all times. This distance will vary with the intensity of the musical passages, from eighteen inches minimum, to about three feet maximum, being close enough to get "presence" but not so close as to pick up excessive sybillant distortions.

In scoring orchestra pickups for motion pictures the most general practice is to score the sound track after the picture is assembled. The picture is then projected on the screen with suitable cues written on the film. The most satisfactory results in music recording are achieved by very close cooperation with the arranger. There are many different approaches to the microphone placement problem in this type of recording, this being largely determined by the specific requirements of the arranger. In some instances it is preferable to suspend it directly from cables attached to the ceiling. At other times a single microphone pickup is used and placed over the conductor's head or behind him. If the arranger prefers to emphasize certain sections of the orchestra at different times during the recording it will be necessary to place microphones at strategic points throughout the orchestra, with the separation of the sections being handled by the mixer. In the case of title music, etc. microphones are usually placed out in front of the orchestra. The actual microphone techniques employed for orchestra pickup do not vary widely from broadcast type techniques or record recording techniques.

Sound effects in motion pictures are quite often recorded at the same time and along with dialogue on the sets. However, there are many sound effects that cannot be reproduced in this manner, such as train whistles, horse run-bys, the noise of brooks and rivers, wind and storm effects, door slams, etc. Due to the acoustics of the set it is difficult to pick up these sounds and reproduce them in a recognizable form. So they are recorded separately or drawn from libraries of previous recorded sound effects, and put on different tracks to be dubbed in later. The pickup of these effects is strictly up to the experience and the discretion of the operators.

In conclusion, since microphone operating technology is a combination of technical know-how, skill, and artistic judgment, it has not as yet been reduced to an exact science, and more than likely never will be confined to scientific definition. Therefore we can only state, in a final summing up, that there is no substitute for good common sense and long experience.

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